Freenet and Chord

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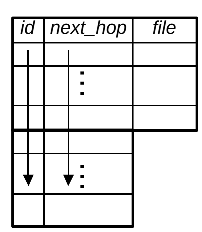
Freenet

- Routing based lookup
  - Queries routed based on routing table
- Each node maintains a routing table with:
  - Key (to index the table)
  - Next hop node (where a file corresponding to the key might be available)
  - Pointer to local copy if one exists
- Searching for a file:
  - Find closest match and route
  - If failure, backtrack
    - "Steepest ascent hill climbing"
    - Ends up performing a DFS-like traversal
  - Routing is a heuristic



Query side effects

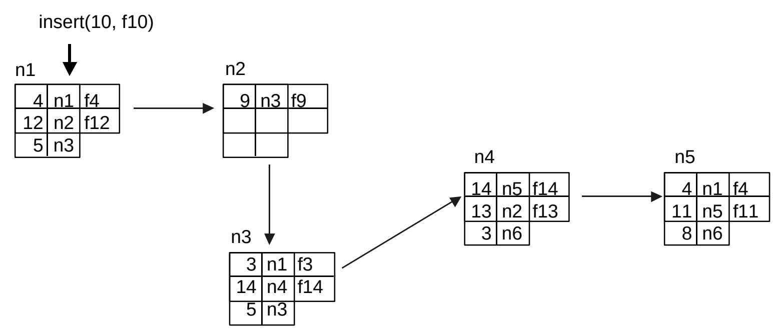
- Query determines a path to a copy of the file
- On the return path:
  - Each node caches a copy of the file
  - Each node remembers the source from which the file was obtained
- Local state on each node:
  - File cache: could be managed as LRU
  - Routing table cache: could also be managed as LRU

Lookup Analysis

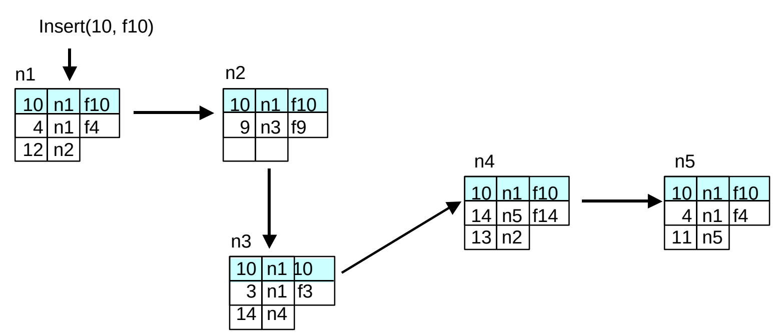
- Paper claims the following effects:
  - Nodes eventually specialize in locating sets of similar keys
    - If a node is listed in a routing table, it will get queries for related keys
    - Will gain more "experience" in answering those queries
  - Nodes become similarly specialized in storing files having related keys
  - Popular data will be transparently replicated and will exist closer to requestors
  - As nodes process requests, connectivity increases
    - Nodes can discover other nodes in the network
- Caveat: lexicographic closeness of filenames does not imply key-closeness

Insertion

- Insertion involves the following:
  - First attempt a “search” for the key
  - If you find a copy, “conflict” is detected and insert is abandoned
  - If no conflict, then insert the file by sending it along the query path



Insertion (contd.)



Analysis of insertion

- Newly inserted files are placed on nodes already possessing files with similar keys
  - Reinforces clustering
- New nodes can use inserts as a supplementary means of announcing their existence
- Attempts by attacker to supplant existing files with junk:
  - Initially insert performs a query
  - Query results in expanding the boundary of what is known
  - Eventually a conflict arises and insert cannot proceed
  - Surprising result: original file is more widely known!

Small World Property

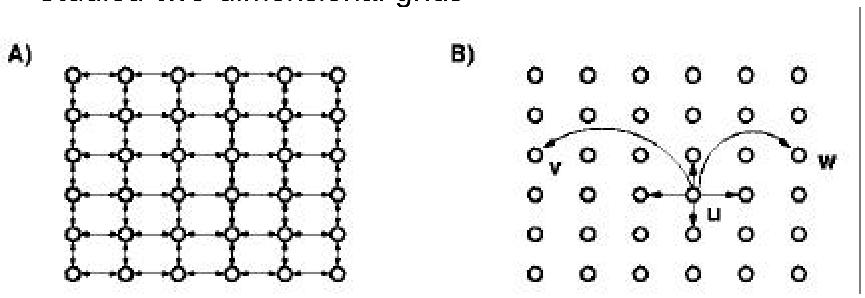
- Original experiments by Milgram:
  - Distance between two randomly selected persons is small
  - The path can be discovered in a distributed manner
- Experiment (1967):
  - 160 letters given to randomly chosen people in Omaha, Nebraska
  - Their target was a stockbroker in Boston
  - Can pass along the letter only through friends
  - 42 made it. Average length: 5.5 hops
- More generally, the setting is:
  - Clustered systems: most of the neighbors of an element are neighbors themselves
  - Still achieve a low diameter

Formal Analysis of Small World Property

- Diameter of uniformly random graphs is not too relevant
- Watts and Strogatz:
  - Rewired ring networks
    - Some short range connections
    - Some long range connections
  - Showed that it has low diameter
  - Number of systems have similar properties
    - Connections among neurons in certain species
    - Power grid in the western US
    - Hyperlink graph of the web
- Kleinberg's study:
  - Addresses the second question: can there be a distributed algorithm that discovers these low distance paths?

Kleinberg's Results

- Studied two-dimensional grids



- Assume that you have a budget for long links
  - Assume that the probability of a long link is some inverse-power of the number of lattice steps
- Distributed algorithm exists only when:
  - Probability is proportional to (lattice steps)$^{-2}$

Using Small World Property in Freenet

- Question: is it possible to make a rigorous use of the small world property in Freenet?

Unstructured Networks

- Summary:
  - Connections between nodes are arbitrary
  - Files/keys are stored on arbitrary nodes
  - New routing table entries are created in a dynamic fashion
- Advantages of unstructured networks:
  - Algorithms tend to be simple
  - Can optimize for other properties: locality, quality of connections, etc.
- Disadvantage of unstructured networks:
  - Hard to make performance guarantees
  - Might result in query failures even though the object exists

Announcements

- Material for upcoming lectures:
  - Today: Chord
  - Wednesday: CAN
  - Friday: Pastry, Tapestry, Skip Graphs
- Assignment 2:
  - Design document due on Friday
  - Review meetings on Monday

Structured Networks

- Commonly referred to as distributed hash tables
- Interesting systems: Chord, CAN, Tapestry, Pastry
  - Hypercube-like systems: Chord, Tapestry, Pastry
  - Multidimensional-mesh-like system: CAN
- Fundamental issues:
  - Try to keep the diameter of the network small
  - Try to minimize the neighborhood state of each node
  - Provide load-balance (in a probabilistic fashion)
  - Deal with dynamic node additions/deletions
  - Exploit locality of underlying network

Chord Overview

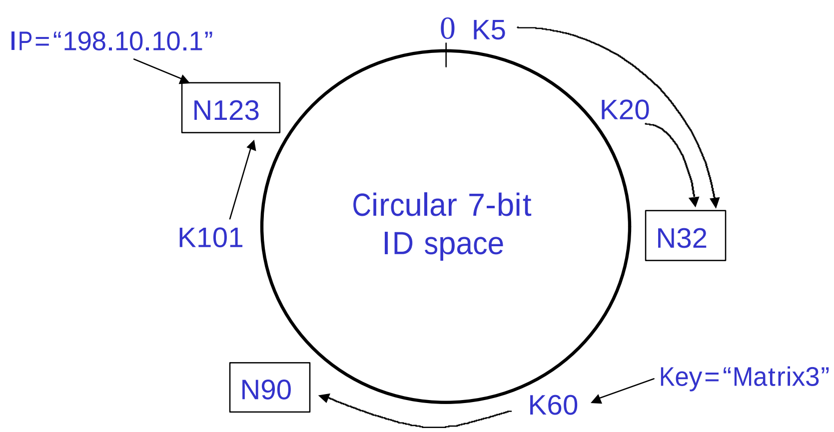
- Provides lookup service:
  - Lookup(key) → IP address
  - Chord does not store the data
- *m* bit identifier space for both keys and nodes
- Key identifier = SHA-1(key)

  Key="Matrix3" —SHA-1→ ID=60

- Node identifier = SHA-1(IP address)

  IP="198.10.10.1" —SHA-1→ ID=123

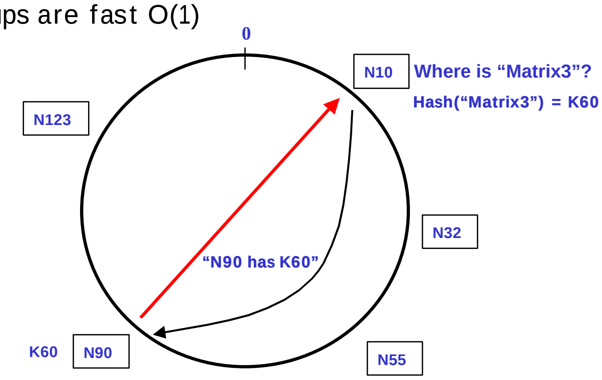
Hashing Scheme



- A key is stored at its successor: node with next higher ID

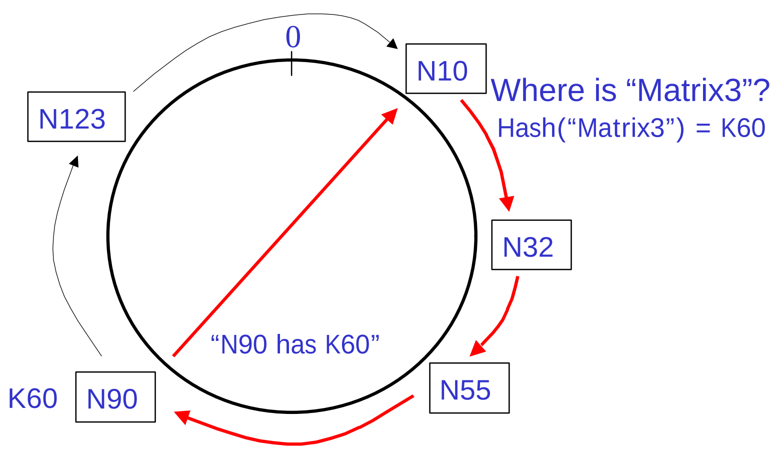
Simple Scheme

- Every node knows of every other node
  - that is, “N10” knows “N90” is “198.20.20.1”
  - requires global information
- Routing tables are large O(N)
- Lookups are fast O(1)



Other Extreme

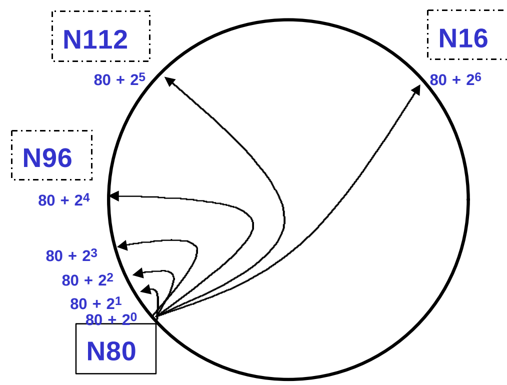
- Every node knows its successor in the ring



- requires O(N) lookups

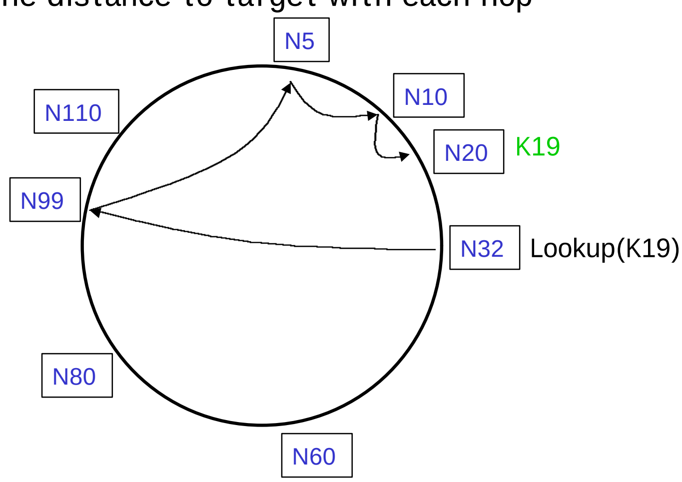
Intermediate solution: "finger tables"

- Every node knows *m* other nodes in the ring
  - That is, it knows the node that is maintaining $K + 2^i$
  - where K is mapped id of current node
- Increase distance exponentially



Faster Lookups

- Lookups take O(Log N) hops
- Halve the distance to target with each hop

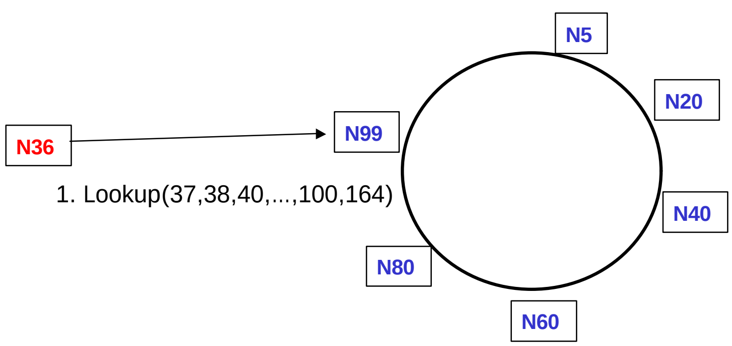


Joining the ring

- Three step process:
  - Initialize all fingers of new node
  - Update fingers of existing nodes
  - Transfer keys from successor to new node
- Less aggressive mechanism (lazy finger update):
  - Initialize only the finger to successor node
  - Periodically verify immediate successor, predecessor
  - Periodically refresh finger table entries

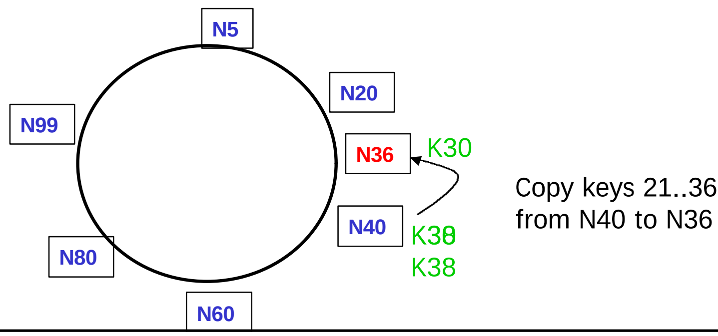
Joining the ring: step 1

- Initialize the new node’s finger table
  - Locate any node *p* in the ring
  - Ask node *p* to lookup fingers of new node N36
  - Return results to new node



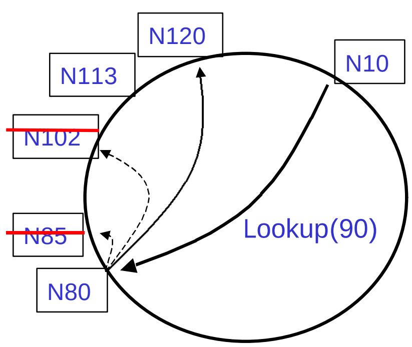
Joining the ring (contd.)

- Step 2: Updating fingers of existing nodes
  - new node calls update function on existing nodes
  - existing nodes can recursively update fingers of other nodes
- Step 3: transfer keys from successor node to new node
  - only keys in the range are transferred



Handling Failures

- Failure of nodes might cause incorrect lookup



- N80 doesn't know correct successor, so lookup fails
- Successor fingers are enough for correctness